Tutorial Assignment 1: Basic Statistical Mechanics

Handwriting should be legible. Calculations should be explained. Units should be given. Numerical answers should be given to 4 significant figures.

1. There are 10 particles in a box. Each particle has two energy levels, ε_1 and ε_2. The probability that a particle is at ε_1 is 0.6, at ε_2 is 0.4.

(i) Find the average population of particles at ε_1, and the average population of particles at ε_2. **[1]**

(ii) Suppose that ε_1 is 1 J and ε_2 is 2 J. Find the average total energy of all particles. **[1]**

2. (i) How many particles are there in 1 mole of particles? **[1]**

(ii) Find the number of particles in 0.5 mole. **[1]**

(iii) How many moles are in 10^{24} particles? **[1]**

3. There are 1 mole of particles in a box. Each particle has two energy levels, $\varepsilon_1 = 0$ J and $\varepsilon_2 = 10^{-23}$ J. The temperature of the box is 1 K.

(i) The particles are distributed among the two levels. State the name of this distribution. **[1]**

(ii) Find the Boltzmann factor for each level. **[2]**

(iii) Find the ratio of the populations in the two levels. Give your answer in the form 1:x. **[1]**

(iv) Find the probability that a particle is at ε_1, and the probability that a particle is at ε_2. **[2]**

(v) Find the population of particles at ε_1, and the population of particles at ε_2. **[2]**

(vi) Find the total energy of the particles. **[1]**

(vii) Suppose that half of the particles fall from ε_2 to ε_1. Find the new populations. Find the loss in energy of the particles. **[3]**

(viii) This fall from ε_2 to ε_1 could happen if there is a decrease in temperature. Write down the Boltzmann distribution formula for each level. **[1]**

(ix) Using these formulae and the new populations, solve for the new temperature. **[2]**

CONSTANTS

Speed of light in vacuum	c	=	3.00×10^{8} ms^{-1}
Permeability of vacuum	μ_0	=	$4\pi \times 10^{-7}$ Hm^{-1}
		=	$4\pi \times 10^{-7}$ VsA^{-1}m^{-1}
Permittivity of vacuum	ε_0	=	8.85×10^{-12} Fm^{-1}
		=	8.85×10^{-12} AsV^{-1}m^{-1}
Elementary charge	e	=	1.60×10^{-19} C
Planck constant	h	=	6.63×10^{-34} Js
$h/2\pi =$	$\hbar$	=	1.05×10^{-34} Js
Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
Boltzmann constant	k_B	=	1.38×10^{-23} JK^{-1}
Gas constant	R	=	8.31 JK^{-1}mol^{-1}
Unified atomic mass constant	m_u	=	1.66×10^{-27} kg
		=	931.5 MeVc^{-2}
Electron mass	m_e	=	9.11×10^{-31} kg
Proton mass	m_p	=	1.67×10^{-27} kg
Gravitational constant	G	=	6.67×10^{-11} Nm^{2}kg^{-2}
Acceleration due to gravity	g	=	9.81 ms^{-2}
Bohr magneton	μ_B	=	9.27×10^{-24} JT^{-1}